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Detonator-Effects Investigation of AXEUMM Experiments

by Matthew M. Biss, Richard Benjamin, Ronnie Thompson,
and William Sickels

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Matthew M. Biss and Richard Benjamin
Weapons and Materials Research Directorate, ARL

Ronnie Thompson
Dynamic Science Inc.

William Sickels
Bowhead Science and Technology LLC

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14. ABSTRACT
AXEUMM experiments were conducted to investigate the presence/absence of jetting at the charge surface of detonating energetic materials due to the detonator employed. Experiments are conducted using gram-range spherical charges in the blast chamber at the U.S. Army Research Laboratory's Detonation Science Facility. Early-time high-speed images of the detonation wave's breakout and air shock wave's early-time expansion are captured using a high-speed intensified camera. Explosively driven air shock waves are qualitatively analyzed throughout their early-time expansion. Captured images are shown to exhibit a nearly spherical air shock wave throughout early-time expansion without the presence of jetting due to the detonator.

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1. Introduction

Detonation and air shock wave measurements are traditionally gathered using full-scale experiments in which charge masses may vary anywhere from 1 to 10^5 kg (*1*). Consequently, the advent of the explosive scaling laws (*2–4*) in the early 1900s permitted the scaling of these widely ranging experimental results for comparative purposes. Nearly a century later, experimental laboratory-scale-based research has been shown to extend the scaling laws' validity down through the milligram range for select materials (*5–8*). In this research, optical flow visualization techniques (e.g., schlieren, shadowgraph, etc.) are combined with high-speed cameras to track explosively driven air shock wave propagation rates for characterization purposes. Captured high-speed images have been shown to provide detonation and air shock wave properties at the interface between the energetic material and surrounding medium (velocity, pressure, particle velocity, and density) in addition to radially varying air shock wave properties (e.g., peak pressure, peak temperature, peak density, and positive pressure duration) (*5–8*). The extension down to the laboratory scale has been demonstrated to be a highly accurate, cost-effective alternative to traditional detonation and air shock wave characterization experiments.

However, some questions exist regarding the validity of these measurements (*8*), due to the possibility of adverse jetting effects introduced by the detonator employed. In response, the present research was conducted to address these concerns and verify the presence/absence of jetting effects in AXEUMM (ARL eXplosive Evaluation Utilizing Minimal Material) experiments as a result of detonator-initiated spherical charges. Experiments were conducted using laboratory-scale spherical charges composed from the energetic compound cyclotrimethylene trinitramine (RDX). A high-speed intensified camera was used to image the detonation wave breakout at the energetic charge surface in addition to the initial propagation of the air shock wave generated. Captured images were qualitatively analyzed for the presence/absence of jetting at the charge surface.

2. Experimental Methods

Experiments were conducted with spherical 13-mm-diameter energetic-material charges. Monolithic RDX charges were pressed to a specified density of 1.77 g/cm^3 using a specially designed pressing die and hydraulic press. Spherical charges possess a centrally positioned right-circular-cylinder void to accommodate an RP-3 (Teledyne-RISI, Inc.) exploding bridgewire (EBW) detonator (29-mg pentaerythritol tetranitrate [PETN]) for initiation, figure 1.

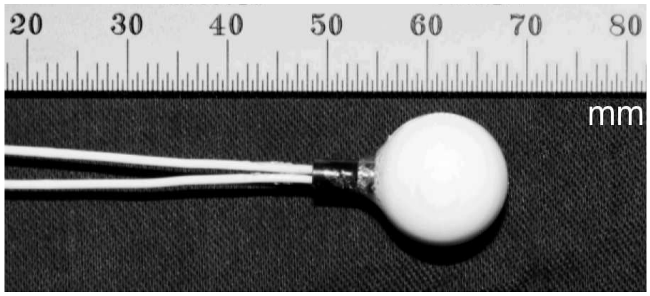

Figure 1. Monolithic spherical charge with centrally positioned detonator.

Experiments were performed in the blast chamber located at the U.S. Army Research Laboratory's Detonation Science Facility. Figure 2 shows the experimental setup used for the present experiments. A xenon flash bulb is triggered to frontlight the charge and obtain a static image of the charge orientation. A Teledyne-RISI FS-43 EBW firing system, charged to 4.2 kV, subsequently initiates the RP-3 detonator, while a PCO-Tech model HSFC-Pro high-speed intensified camera records the explosively driven air shock wave propagation history. The resulting explosive fireball and subsequent ionization of the surrounding air due to the shock wave provide self-illumination for the duration of the record. The generated air shock wave is imaged for a total of three charges. Pressed charge properties and camera settings are tabulated in table 1.

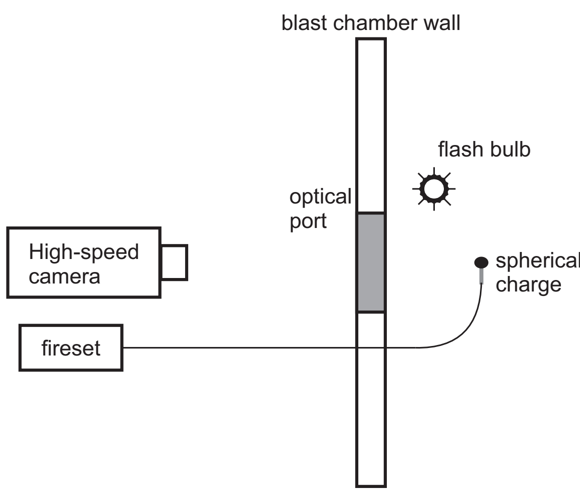

Figure 2. Experimental imaging setup.

Table 1. Tabulated charge properties and camera imaging variables.

Shot #	**Density** (g/cm^3)	**Mass** (g)	**Frame rate** (frames/s)	**Exposure** (ns)
12354-1	1.77	1.823	1,000,000	100
12354-2	1.77	1.821	1,000,000	40
12354-3	1.77	1.826	1,000,000	40

3. Results and Discussion

High-speed images were qualitatively analyzed to determine the presence of jetting at the charge surface (specifically the surface opposite the detonator) and to verify the early-time expansion shock wave sphericity. A composite image was constructed for each experiment from the captured high-speed image sets, figures 3–5. As shown, all three composite images lack any semblance of jetting at the specified surface. Additionally, air shock waves were determined to tend toward sphericity by the second frame following detonation wave breakout for all image sets. The initial image following shock wave breakout was anticipated to be aspherical, as the detonator is unable to act as a perfect point source initiator and therefore results in a slight variation of the detonation wave's breakout along the charge surface as shown. However, this does not affect previous measurements, as they were acquired from the surface normal to the detonator axis, therefore ensuring a normally propagating shock wave (*8*).

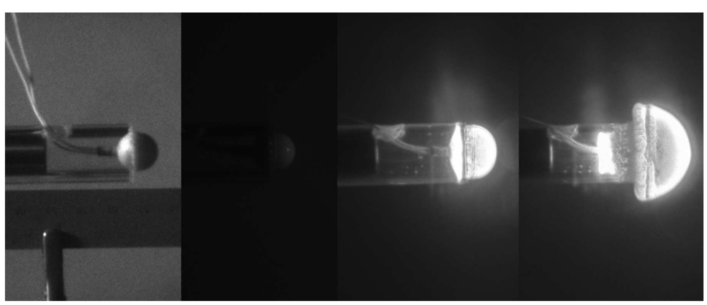

Figure 3. Composite image generated from high-speed images for shot 12354-1.

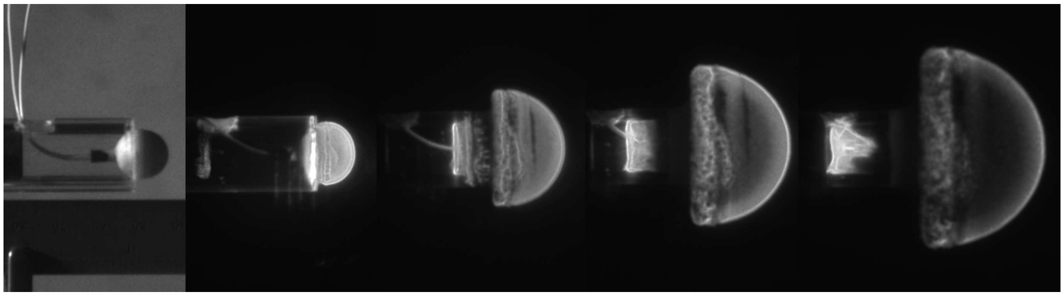

Figure 4. Composite image generated from high-speed images for shot 12354-2.

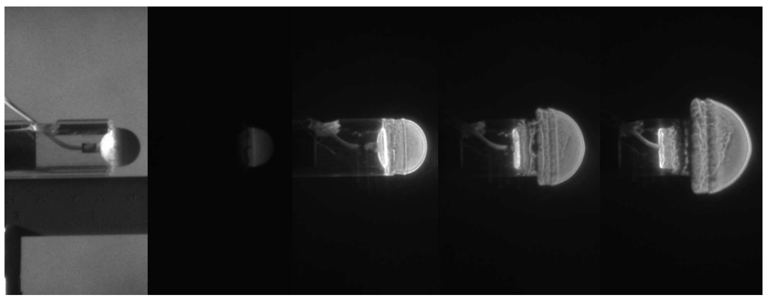

Figure 5. Composite image generated from high-speed images for shot 12354-3.

4. Conclusions

AXEUMM experiments were conducted and investigated for the presence/absence of jetting due to the detonator in addition to shock wave sphericity. High-speed images were gathered for multiple experiments to capture the detonation wave breakout at the energetic charge surface and initial air shock wave propagation history. The air shock wave was determined to be spherical in nature for all image sequences and lacked any semblance of jetting at the surface of interest. It was therefore concluded that prior measurements taken along this surface (*8*) were valid and acceptable for characterization purposes.

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